European Partnership on Metrology
Call 2024 –Digital Transformation, Green Deal, Normative and Research Potential

Selected Research Topic number: **SRT-d01**
Version: 1.0

Title: Traceability for industrial 3D digitalisation by advanced scanning systems

Abstract

3D scanning systems are vital for the digital transformation of geometric measurements. Such scanning systems are increasingly replacing classical dimensional measurement in (i) fast in-line inspection in the automotive or aerospace industries, (ii) construction and data collection for building information modelling, (iii) hazard monitoring in surveying, and (iv) cargo logistics. To support the increasing use of 3D scanning systems trust must be increased and traceability provided for the measurements and information based on point clouds generated by 3D scanning systems. Validated digital metrological twins (D-MTs), practical assessment of the point cloud quality, and independent verification datasets for proprietary analysis software and good practice guidelines are all needed. In addition, robust measurement uncertainties for position, size and shape need to be determined. When using standard forward-propagation of uncertainties for 3D scanning systems, it results in unmanageable matrix sizes and impractical processing time, therefore, this needs to be address and demonstrated using industrial case studies.

Keywords

3D scanning system, point cloud, digital metrological twin, traceability, system modelling, data fusion, dimensional metrology, measurement uncertainty, data quality.

Background to the Metrological Challenges

3D scanning is used to create real-life digital twins in mechanical engineering or in the construction industry and provides time-efficient data acquisition with comprehensive dimensional information on the measurand. The European Commission's Directorate-General for Research and Innovation identified digital twins as one of six enabling technologies supporting Industry 5.0, as they considerably simplify and significantly speed up the capture of complex geometries or features that are difficult to access with point probes.

3D scanning systems and digital metrological twins (D-MTs) can also provide in-line and non-destructive metrological methods for defect detection and characterisation. Consequently, stakeholder demand for dimensional measurements is shifting from sparse high-accuracy measurements to fast acquisition of copious data points of lesser accuracy. However, this puts increased pressure on data post-processing, and the very large amount of data is challenging and requires dedicated computing architecture with sophisticated data-analysis, often using proprietary software tools.

This data analysis complexity, as well as the limited interoperability of some laser scanning platforms are considered the major challenges to the broader application of 3D scanning and D-MTs in architecture, engineering, and construction. The increasing use of 3D scanning in critical areas such as high-quality engineering or geodetic hazard monitoring, also needs accurate measurements and reliable estimates of measurement uncertainty. Typically, the uncertainty of the individual coordinates is worse compared to single-point sensor systems. However, the measurand of interest is, in most cases not the point cloud itself, but derived characteristics such as inclination, volume, or defects in in-line inspection using either geometric or radiometric features.

Currently, ISO 10360-13 (Geometrical product specifications) defines acceptance and verification tests and provides guidance for the assessment of the achievable uncertainty for a selection of geometric features, but this is only for industrial applications in well-defined and well-controlled environments. In contrast, there are many different functional models for specialised 3D scanners and existing error compensation strategies have been demonstrated to have limited precision. The classic approach of focussing on the instrument for conclusions about the measurement uncertainty of the result is unsuitable for 3D scanning. The influence of the environment on the probing beam (e.g. due to temperature gradients) needs to be considered given the large measurement volumes in uncontrolled environments. Further to this, steps in the post-processing chain, the fusion or registration of multiple scans and model-based analysis can also introduce further sources of uncertainty, whilst also reducing the impact of the individual coordinate uncertainty on the final measurement result.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on metrology research necessary to support digital transformation and traceability in industrial 3D measurement technology based on scanning systems.

The specific objectives are

1. To develop measurement models for use with digital metrological twins (D-MTs) of 3D scanning systems including instrumental, environmental and target influences on the measurement result. A modular approach should be followed to allow model refinement and adjustment to different measurement scenarios and different scanner configurations. The generated large point clouds of the models or D-MTs should be in format compatible with existing commercial 3D analysis software. The measurement uncertainty of the point clouds should be determined following the GUM (Guide to the Expression of Uncertainty in Measurement) and its supplements.
2. To assess the quality of point clouds in dimensional metrology through comparisons using a variety of measurement standards with typical (i) dimensions, (ii) features and (iii) materials generated with 3D scanning systems, and D-MTs of those instruments. In addition, to develop advanced prototypes for critical systems in metrology-class surface scanning devices. Based on these results and the measurement uncertainty, a metric should be determined for the metrological quality of point cloud(s) generated by 3D scanning systems.
3. To develop and establish reference datasets for the assessment and verification of software tools deriving geometric or radiometric features from point clouds. The reference datasets must be suitable for deriving the achievable measurement uncertainty, and data fusion of multiple scans, should be part of the verification scenarios (where appropriate). Datasets should comprise (i) classical geometries such as spheres, planes, cylinders and (ii) more complex geometries typical for two or more applications from industrial metrology, aerospace, or geodesy.
4. Using the outcomes of Objectives 1-3, to (i) develop guidelines for the uncertainty assessment and object classification of geometric and radiometric features derived from large coordinate point clouds, (ii) to determine the measurement uncertainty of target measurement features, using case studies from industrial metrology, aerospace, or geodesy, and (iii) to design and establish novel calibration or verification services for scanning systems.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (e.g. manufacturers of 3D scanners, developers of data processing and analysis software), standards developing organisations (ISO/TC 712/SC6, ISO/TC 28/SC2, ISO/TC 213/WG10) and end users (e.g. mechanical engineering, automotive and/or aerospace industries, construction, logistics).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, standardisation and regulatory bodies, and other European Partnerships is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP IND53 LUMINAR, EMPIR 17IND03 LAVA, 18SIB01 GeoMetre and 20IND02 DynamMITE, and Metrology Partnership 22DIT01 ViDiT and 23IND12 ADAM projects and how their proposal will build on those.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.4 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your proposal's results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the engineering, manufacturing, automotive and aerospace industries, geodesy and construction sectors.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)"

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Timescale

The project should be of up to 3 years duration.

Additional information

The links provided in this section are only correct at the time of publication up until the end of the Call year.

The references below were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] *EMN for Advanced Manufacturing Strategic Research Agenda* https://www.euramet.org/european-metrology-networks/advanced-manufacturing/strategy/strategic-research-agenda

[2] *EMN for Mathematics and Statistics Strategic Research Agenda* https://www.euramet.org/research-innovation/metrology-partnership/strategic-research-and-innovation-agendas